



RELATIONSHIP BETWEEN CARBON DIOXIDE LEVELS AND REPORTED CONGESTION AND HEADACHES ON THE INTERNATIONAL SPACE STATION

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Richard Cole
Chris Coble
Millennia Young
Sara Mason
Mary Wear
Jason Bowman



Study Rational



- Congestion is a frequently reported spaceflight symptom
- Most crewmembers report using congestion meds during ISS missions
- Some findings challenge the historical attribution to fluid shifts
 - Fluid status equalizes during first week of spaceflight
 - Congestion continues to be reported throughout mission duration
 - Anecdotaly reported in relation to ISS CO2 level



Goals



- Look for correlation between congestion and:
 - CO2
 - Headache
 - Age of crewmember
 - Mission duration
 - Age of ISS
 - Volume of ISS

- Primarily from Major Constituent Analyzers (MCA) in USOS
- Back-up sensors used May 13, 2011 to Jan 28, 2012 due to MCA issues
- Missing data addressed with multiple imputation
- 24hr and 7 day average and peak CO₂ levels computed
- First 7 days of space flight excluded to control for inability to obtain CO₂ levels from transport vehicle



https://www.nasa.gov/mission_pages/station/multimedia/gallery/iss030e047174.html



Methods: Medical Data



- PMCs with reported episodes of headaches, congestion or congestion-like symptoms identified and merged
 - Expeditions 13 to 30 from existing data sets
 - First 7 days of space flight excluded to control for fluid shifts
 - 24 astronauts, 71% male, mean age 47.6 (40.1 – 56.7)
 - 529 PMCs in total merged database
 - 458 PMCs occurred after the first 7 days and were included in the study
 - Of the 458 PMCs used:
 - 26 reported congestion
 - 12 reported headache



Exclusion Criteria



- First 7 days of space flight
 - Control for fluid shifts
 - Control for inability to obtain CO₂ levels from transport vehicle



Methods: Analysis



- SAS 9.4 statistical software
- Analysis completed using mixed effects logistic regression
- Random effect intercept term per individual used to adjust for longitudinal repeated observations
- Multiple imputation used to adjust for missing data



Results



Descriptive Statistics for CO2 Variables

Variable	N	Mean	Std Dev	Median	Min	Max
Avg 24hr	458	2.9427	0.8476	2.8678	1.0029	5.4937
Peak 24hr	458	3.5347	1.0815	3.3937	1.1896	7.9000
Avg 7d	458	2.9733	0.7341	2.9246	1.1174	5.0514
Peak 7d	458	4.2660	1.2463	4.1910	1.4730	8.1156

*First 7 days of spaceflight excluded

Average 24hr and 7d values had best statistical significance and were used for next stage of analysis and modeling



Goals



- Variables in relation to congestion

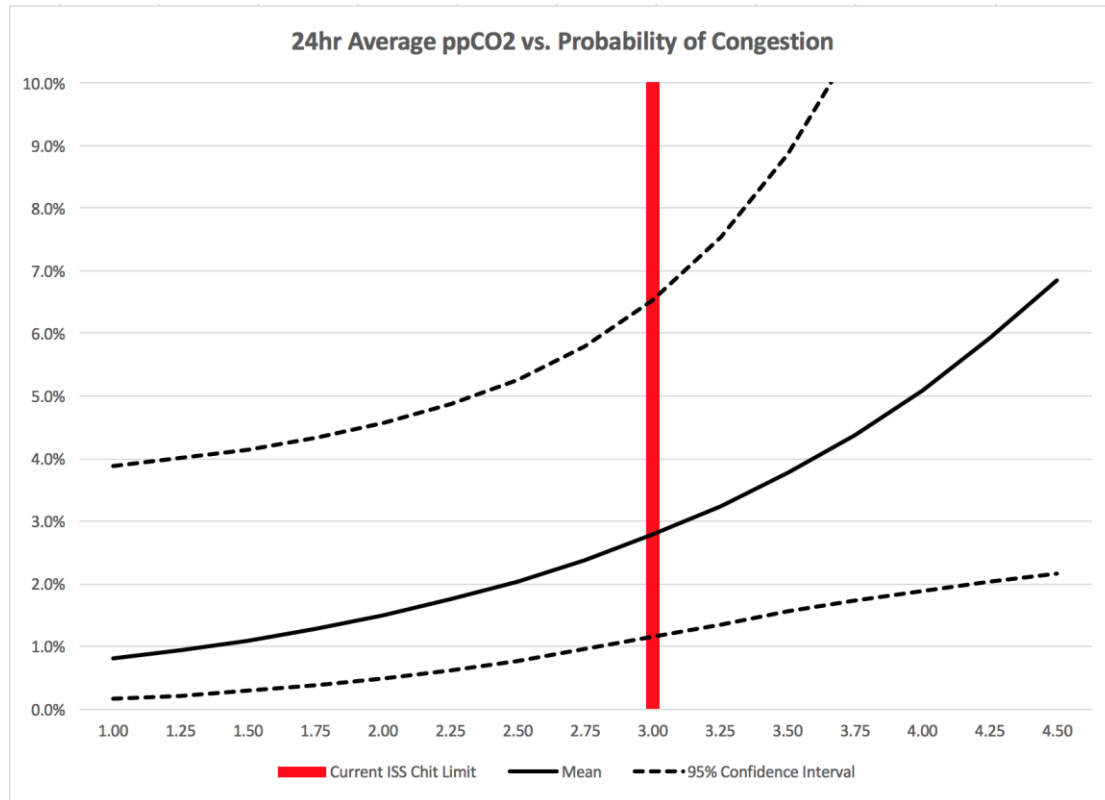
Variable	Coefficient Estimate	Multiplicative Effect (95% CI)
Average 7-Day CO ₂	0.733	2.082 (0.884 – 4.903)
<i>Average 24-hour CO₂</i>	<i>0.630</i>	<i>1.878 (0.901 – 3.913)</i>
Age of ISS (years)	0.616	1.852 (1.025 – 3.348)
Age of crew member at launch	0.263	1.301 (1.016 – 1.666)
Mission time elapsed (days)	- 0.008	0.992 (0.983 – 1.002)
Volume of ISS (not including shuttles)	0.001	1.001 (1.000 – 1.001)

- Association between congestion and headache

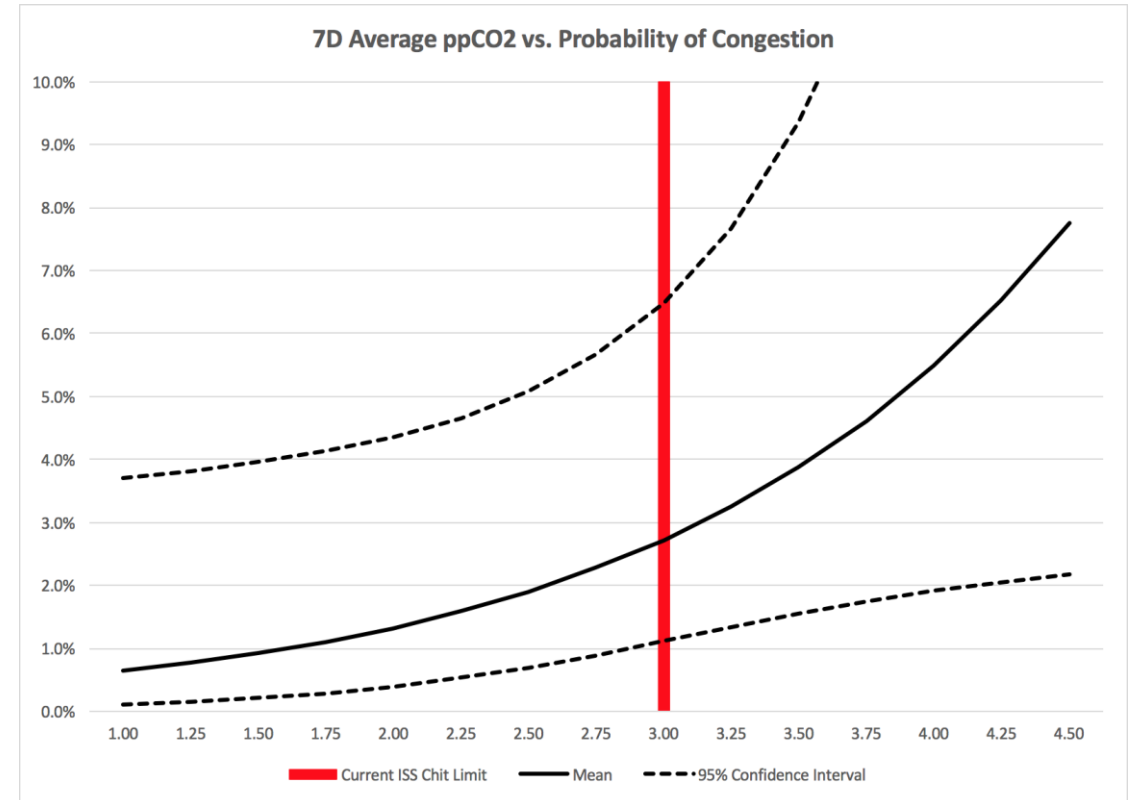
Variable	Coefficient Estimate	Multiplicative Effect (95% CI)
Congestion	2.006	7.435 (1.577 – 35.051)

Probability of Congestion Compared to CO2 Level

24 hour ppCO2 Average

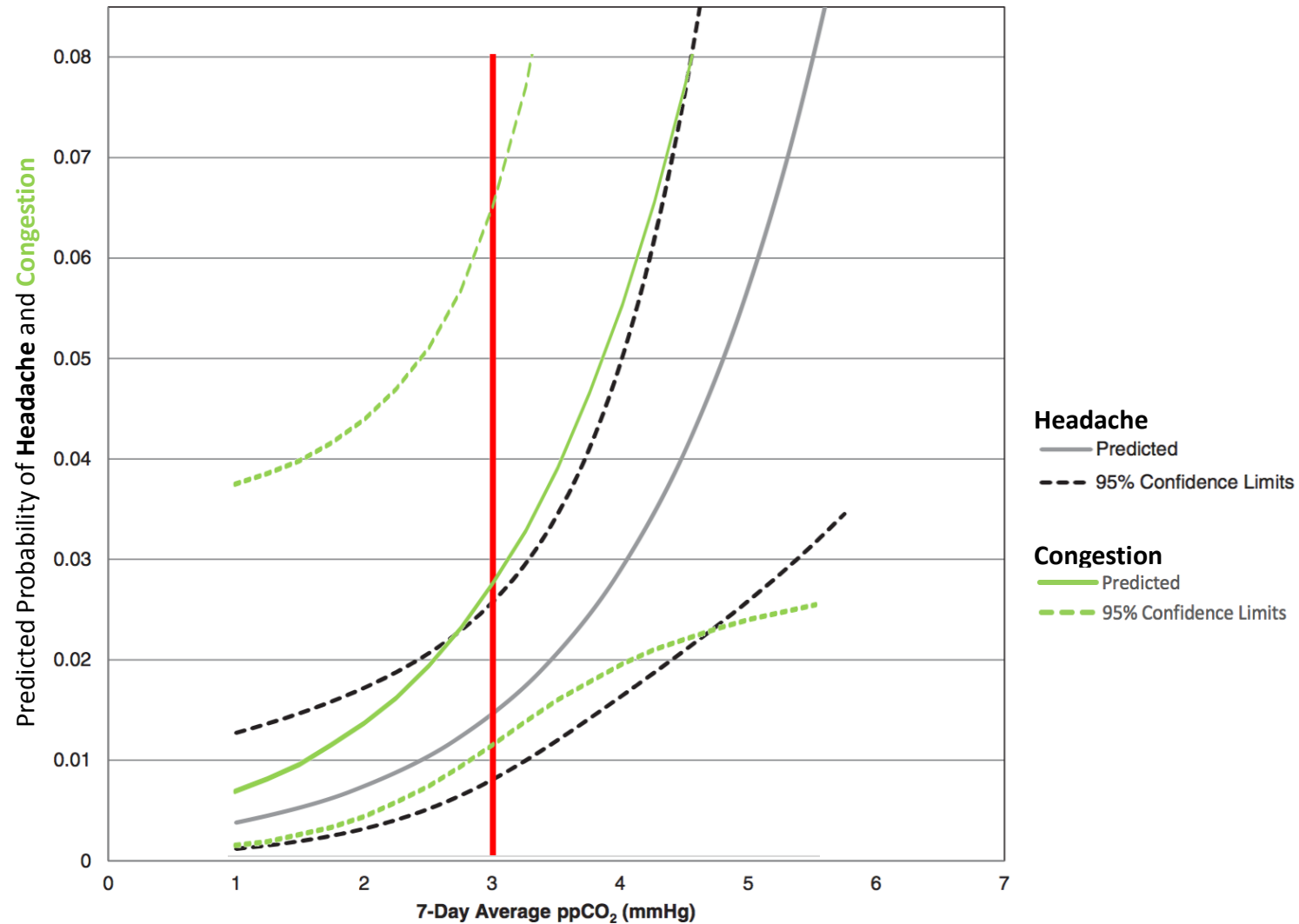


7 Day ppCO2 Average





Probability of Headache and Congestion Based on CO₂

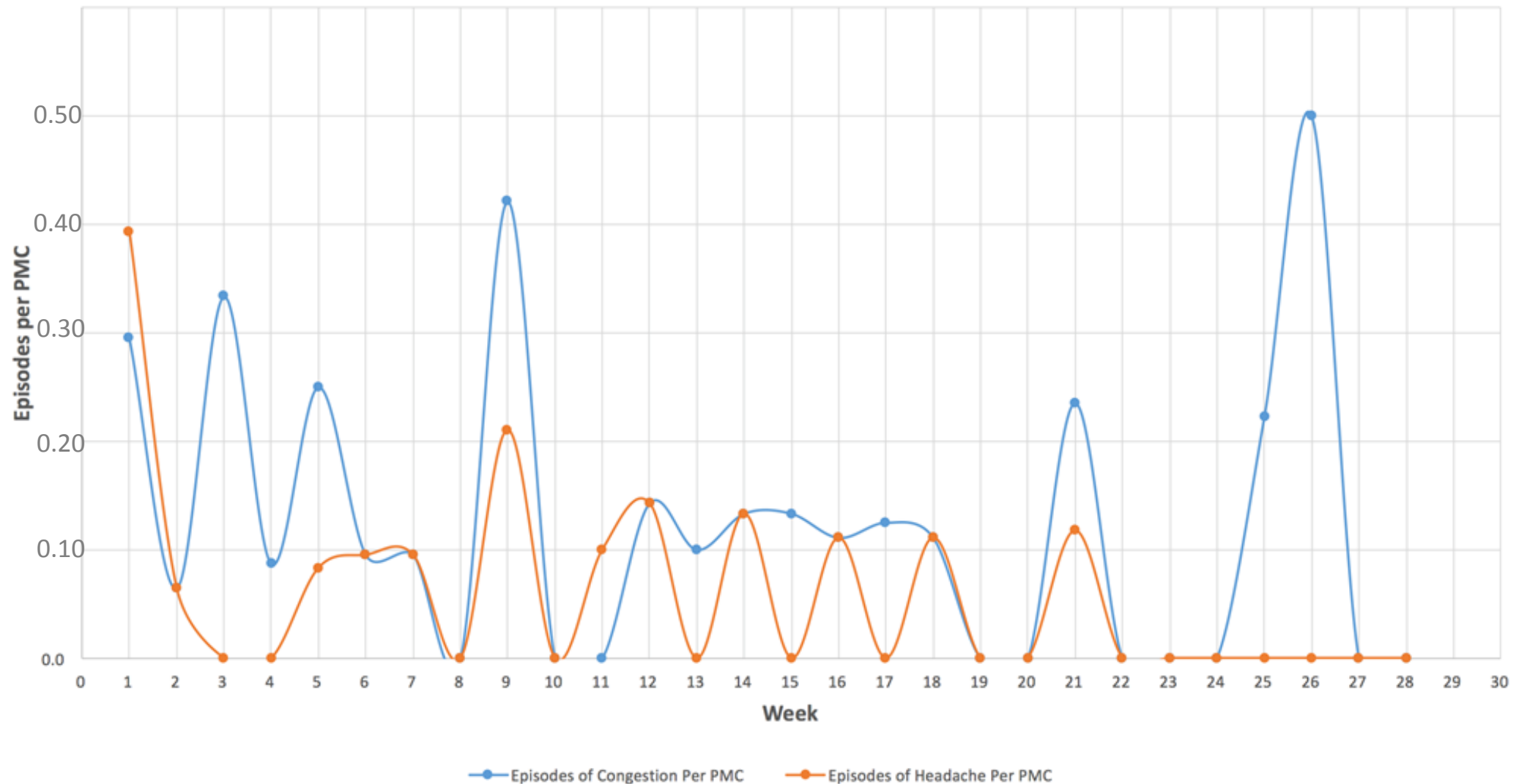




Episodes of Congestion and Headache per Week



Average Episodes of Symptoms, Normalized By # of PMCs, Per Given Week





Limitations



- Did not account for localized pockets of CO2
- Some PMC reports were missing
- Under-reporting is likely
- Congestion and headaches are multifactorial
- Human variation to CO2 exposure
- All retrospective data
- Demonstrated associations but can't prove cause and effect
- EVAs with 100% oxygen for hours, and different CO2 values than on ISS.
- Continued to count ISS CO2 levels after shuttle undock to landing



Conclusion



- Congestion was significant with both CO₂ levels and headache
- Congestion odds double for each 1 mmHg increase in CO₂
- To keep congestion risk under 5%, CO₂ would need to be maintained below 4 mmHg. To keep risk below 1%, CO₂ should be kept below 1.5 mmHg
- Congestion may be an early CO₂ related symptom when compared to headache
 - Not enough data to correlate time course between CO₂ and Headache
 - Congestion and headache probability curves are parallel when based on CO₂